International Approaches to Computer Science Education: A Literature Review

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As with most fields of study, computer science education was born out of, exists in symbiosis with, and will evolve in response to the needs of its industry at large. The computer science industry is unique in that advancements in its products and services have direct implications for every other discipline. In the digital age, computer scientists are humanity's pace-setters. Everywhere around the world, they have been outrunning their own governments and systems of education, such that there now exist severe gaps in primary and secondary educators' abilities to prepare their students to fill the needs of the computing industry.

Fortunately, according to Code.org, "Computer science is one of the few policy issues that can address both foundational education needs and workforce development demands for a state's future workforce" (Code.org, 2018, p. 4). While developing the foundational hard programming skills and computing knowledge needed to enter the profession with promise, computer science education also synthesizes computational, critical, and creative thinking skills that may be present elsewhere in the curricula and directs them toward a pursuit that is both extrinsically and intrinsically rewarding. Thus, with guidance from industry leaders and post-secondary educators, primary and secondary education policymakers are beginning to wrestle with the quality and quantity of computer science education in their constituencies.

Scope of Inquiry

This review synthesizes literature from three different countries: Argentina, France, and Turkey. These nations were selected as representations of potentially different approaches and different outcomes with regard to the conception and implementation of computer science education models. In reviewing the available literature, attempts have been made to answer the following research questions:

- What policies are in place to support computer science education in primary and secondary schools?
- What pedagogical methods or resources are used to achieve curricular aims?
- What are the needs of post-secondary computer science programs and the industry?

The political realities of these computer science landscapes range from decentralized, grassroots organization to full-scale, top-down frameworks.

Summary of Findings

Argentina

According to the Chamber of Software and Computer Services Companies, the information technology sector of Argentina requires around seven thousand new professionals each year, but less than half of those jobs are able to be filled (Del Rio, 2016). While post-secondary computer science education can be relied upon in most countries to produce capable graduates, Argentinian business leaders have become frustrated with university graduates who do not have the requisite skills (Ospina, 2017). In response, several of these individuals came together to form the Digital House coding school, which primarily operates as a grassroots organization outside of any formal educational system. However, partnerships with the Ministry of Education have allowed the school's programs to lead to professional certification, and its curricula have been adopted by a number of secondary schools in and outside of Argentina. The instructional model at Digital House is rooted in the realities of the job experience: there exists ample space for collaboration ("co-working" and "co-learning"), classes focus on acquiring skills that can be of use to many different companies, and job fairs and mock interviews acquaint students with career possibilities and networking opportunities (Del Rio, 2016). According to their website, Digital House has served 4,500 students in 2019 (Digital House).

Beyond that reach, the government of Argentina announced in 2015 an initiative to create a network partnering primary and secondary schools that did not teach programming with those that already taught it independently, allowing the schools to share resources and support each other (Pellettieri, 2016). The program facilitated free university courses to train teachers. Students, educators, and policymakers alike are pleased with the results. However, the demand for workers is so high that educators worry companies will siphon students away from their studies in order to begin working early – a phenomenon that frequently occurs.

France

While Argentina's approach to making computer science accessible to all is still in its infancy (with the technology industry yet to see a strong influx of workers), the nation of France has a long history of computer science education. Baron et al. describe informatics courses in technical high schools as early as the late 1960s. Between 1970 and 1980, the French government launched "the 58-high-school experiment" which utilized university specialists to train networks of secondary teachers and provided fifty-eight high schools with mini-computers (Baron, Drot-Delange, Grandbastien, & Tort, 2014, p. 11:4). The authors note that this initiative was "spurred by the belief that informatics could profoundly change teaching and learning" (p. 11:4). Computer science has been a fixed presence in French schools in the ensuing decades, but different philosophies – from compulsory to elective, centralized to localized, and integrated to explicit – have alternately taken precedent.

In the early 2000s, the French system of computer science education trended toward an unsustainable mix of nebulous classroom integration and explicit assessment. The Ministry of Education prescribed that junior high school students were to be assessed for their skills in computer science and informatics during the course of regular classroom activities, which were encouraged not to be explicitly computing-related, but required the use of technology to accomplish other learning targets (Baron, Drot-Delange, Grandbastien, & Tort, 2014, p. 11:6). While this assessment included some basic computer science concepts, it was in reality a checklist of digital literacy and citizenship competencies. Teachers were not provided with sufficient training to recognize these skills, nor were they supposed to spend class time exploring the theoretical basis for them, which led to situations involving students who knew how to use technology without knowing how it worked (p. 11:12).

Today, the state of computer science education in France is similar to that faced by other nations: all stakeholders understand the importance of computer science training in the secondary schools for workforce development, but policymakers are slow to adopt changes to the fundamental primary curricula to accommodate deep computational thinking skills, “beyond the mere usage of hardware and software” (Baron, Drot-Delange, Grandbastien, & Tort, 2014, p. 11:16). Bridging the gap between foundational mindsets in the primary grades and explicit skills in the upper secondary grades is a chief concern, and Baron et al. recommend further research into plugged and unplugged pedagogical approaches, as well as consensus-building with regard to what content should be taught.

According to the joint Informatics Europe & ACM Europe Working Group on Informatics Education, the European economy is in risk if European nations cannot standardize and make compulsory education in informatics (Informatics Europe & ACM Europe Working Group on Informatics Education, 2013, p. 17). The working group was severe in their assessment of the situation, saying that “European nations are **harming their primary and secondary school students**, both educationally and economically, by failing to offer them an education in the fundamentals of informatics” (p. 17). Like in Argentina, the growth of the technology industry in France is outpacing the growth of the skilled workforce. Rather than draw from a labor pool of non-graduates, the government this year announced a plan to radically recruit talent from outside of France with a generous "tech visa" (Borlongan, 2019).

Turkey

Computer science has been a facet of Turkish education in some form since as early as 2012. This course – "Information Technology and Software" – featured problem-solving and programming with additional attention focused on computer literacy and digital citizenship (Kert, Kalelioglu, & Gülbahar, 2019, p. 133). In 2017, this course was updated and the Ministry of National Education of Turkey partnered with Google to standardize a protocol for the development of educational materials and activities. Kert et al. analyzed the outcomes of a computer science program delivered to students at the junior high school level. The authors noted that schools in Turkey vary widely in their access to the Internet and computing technology required for plugged activities; the program included a large collection of unplugged lessons to ensure equity (p. 136).

Policymakers in Turkey understand the importance of this subject and have mandated it inclusion in the general curriculum. However, this inclusion "has not always led to the effective implementation of this curriculum by all teachers, and has not ensured that all students receive adequate and effective computer science education" (Kert, Kalelioglu, & Gülbahar, 2019, p. 145). Many Turkish teachers do not feel confident in their abilities to adequately facilitate computer science learning due to their own lack of experience. As a result, the Ministry of National Education conducted a review of teacher training programs and discovered a direct correlation between professional development and student achievement in computer science (p. 146). The results of this study were positive, and, as is the case in Argentina, indicate a promising future of educational policymakers partnering with the private sector to understand industry needs and develop curricula. Turkey is a young country, with over 25% of the population under the age of 15. The Turkish government has in recent years invested heavily in technology education and the growth of startups, with over 680,000 teachers being trained by the end of 2019, grants being awarded to Internet startups, and a goal of doubling the percentage of GDP from technology-based companies by 2023 (Turkish Heritage Organization, 2015).

Conclusion

Common threads pervade computer science education throughout the world. Policymakers understand the importance of providing a quality education in computational thinking and programming to students as early as primary school. Realizing the gravity of the technology labor force crisis, governments have searched for innovative ways to compete in a global marketplace – not only in an effort to attract companies, but also to produce a reliable workforce. Turkey, comparatively late to introducing computer science to schools and still without sufficient infrastructure in some places, is attempting to work with the private sector to present a nationalized system that works for all parties and exposes the field to children early. In Argentina, the government is co-opting a model which the technology industry developed to great success in a process of forced self-sufficiency. France, where the growth of the computing industry is far outpacing the evolution of the educational system, is forced to recruit talent from other nations. Methods that work all involve a mix of plugged and unplugged lessons, sensitivity to equity in the system, and a standardized curriculum that begins in the primary grades. Teachers' self-perceptions of their abilities is a hurdle, but addressing it pays dividends in student achievement. There is much work to be done, and there are different ways of achieving results, but each of these countries are meeting their goals with promise.

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